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The Digital Mock-up as a Virtual Working Environment within the Development Process

Steffen Kaun
European Aeronautic Defence and Space Company
Military Aircraft
81663 Munich, Germany

Steffen.Kaun@m.eads.net

0. Abstract

The need for a reduction of engineering time and cost during the last years made an optimisation of the development processes inevitable. In order to defend their market shares, all companies were forced to employ more efficient development methodologies and to bring all their software tools up to date. As a result the CAD world for new projects has essentially changed from the 2D to 3D world. However, from an early stage it became evident that 3D modelling alone was not sufficient to achieve the required benefits. It was realised that only with a sensible administration and steering of all the new 3D data can the advantages of a virtual working environment be fully utilised.
The realisation of a Digital Mock-up (DMU) requires design methodologies and processes adopted to the companies needs that will ensure that all data is up to date and of good quality.

This presentation will discuss the realisation of a virtual working environment in military aircraft development. The DMU world with CATIA, 4D-Navigator and VPM at EADS Military Aircraft in Ottobrunn, Germany is described exemplary.

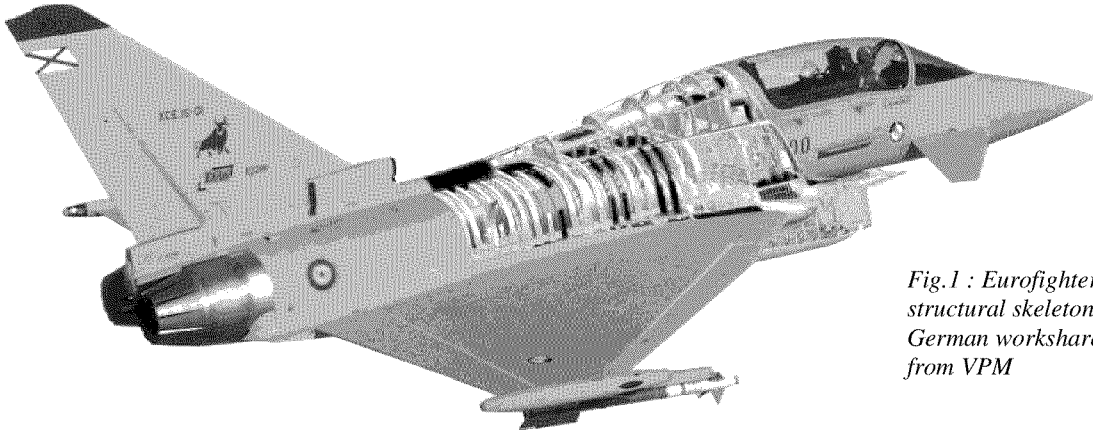

Fig.1 : Eurofighter with the structural skeleton of the German workshare loaded from VPM

Paper presented at the RTO AVT Symposium on "Reduction of Military Vehicle Acquisition Time and Cost through Advanced Modelling and Virtual Simulation", held in Paris, France, 22-25 April 2002, and published in RTO-MP-089.

1. The Design Environment in the Past

All the military aircraft projects during the last years like Tornado, Phantom, MIG29 used a drawing based design methodology in which drawing trees, bill of materials and effectivity sheets together created a configured product structure.
It was the task of the designer to prepare the required design context. By doing this he had to contact all the affected system developers (fuel, hydraulics, electrics, environment control, ...) and the personnel from the airframe design. Very often the responsible person was on a business trip, on holiday or just out for lunch. So a long time was needed just to collect the required information. And in the end the designer was not sure if he had not forgotten some important details.
Clearance checks were performed either on the drawing sheet with the help of a lot of additional views or in a hardware mock-up. Installation and deinstallation investigations also needed a hardware mock-up. But in those wooden or metal mock-ups only one variant was shown.

Also with the old tools it was possible to develop good aircraft, but the effort needed to do all the design work was labour intensive. A realistic parallel design of structure and all systems was not possible or at least combined with a lot of difficulties.

2. The Digital Mock-up (DMU)

Necessity

The commission to develop a new series production fighter aircraft a few years ago forced all the concerned engineering departments in Europe to deliver product data under extreme cost and time pressure.
This was not possible any more with the "old" design methodologies and tools (like 2D CAD systems) as used in the past.

A requirement existed to develop a complex product with:

- a high packing density
- whose single components can only originate in their environment
- all within a tight timeframe
- requiring concurrent development of all systems
- an increasing amount of variants (making "real-life" mock-ups unachievable)
- an ability to integrate existing processes and tools.

These points led the CAD and PDM departments to find a specific DMU solution that utilises existing design methodologies along with developing software that is adopted to the companies every single need.

At EADS Military Aircraft therefore a DMU working environment was created with CATIA V4, 4D-Navigator and a customised EnoviaVPM.

Requirements

In each international military aircraft project tools and processes have to be found or developed that are able

- To handle around 15000 parts (without standard parts) in the workshare of one participating partner company
- To handle around 50000 parts (without standard parts) in the whole aircraft
- To manage up to 200000 CAD models
- To cover the versioning process
- To navigate in the product structure
- To deal with a vast number of variants
- To provide all the analyses for an integrated design
- To integrate both original and reduced geometry
- To enable a new form of data exchange for geometry, product structure and positioning data with development partners and suppliers because the old way of exchanging microfiches is not able to cover all the necessary information.

Certainly all provided data must be reliable and up to date. Incomplete or obsolete information more often leads to non-acceptance of the new system.
Also the performance of the system must be agreeable by all users concerned. Loading of CAD data from the DMU for example should not take much longer than reading filebased models.

Definition

All requirements can only be met by a definition of the Digital Mock-up as follows:

The Digital Mock-up is a complete virtual product environment for the whole process of 3-dimensional development and maintenance of a complex product including configuration and change management.

All design work has to be done within the DMU world. The designer must fully embrace this new technology, entering the DMU environment first thing in the morning, thus carrying out all design tasks in it throughout the entire day.
All the investigations that are done in a separate environment or on a single sheet of paper disappear sooner or later and are not usable for others.
On the other hand care has to be taken that the designers do not feel intimidated or controlled by the system. They should not lose their freedom to be creative.

Prerequisites in the Design Process

The purchase of a new software on its own is definitely insufficient to form a Digital Mock-up. Some prerequisites in the design process must be fulfilled, like

- Part based methodology of working
- Modelling according to the rule “one part – one CAD model”
- The master of the geometry is the 3D model

- Definition of modelling rules, that have to be followed strictly
- High level detail modelling needed
- All the drawings (if needed at all) have to be derived from the 3D models (see fig.2).

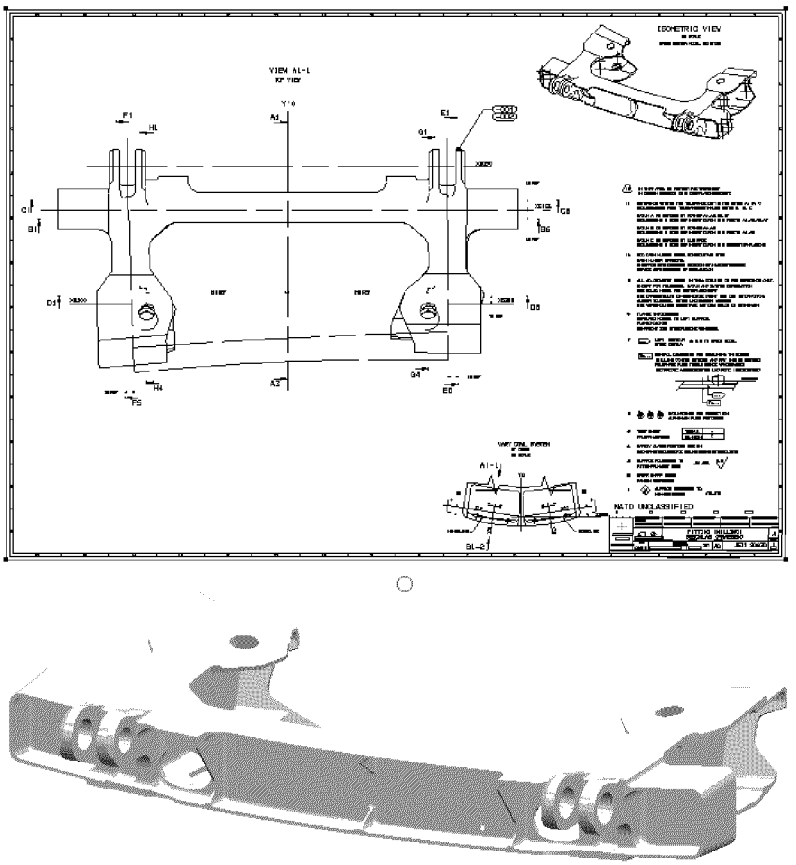

Fig.2: Master 3D model with derived drawing

Without the fulfilment of these prerequisites it is not possible to obtain all the advantages out of the new data management systems and the new 3D CAD tools.

3. The New Design Process

The understanding of the Digital Mock-up described above leads to a DMU working process that starts with the concept and definition phase, which covers pre and detailed design as well as supporting all development departments during modification phases.

With the introduction of this new working environment the working process of all concerned departments changes basically. Part based data management is mandatory. Parallel development of all the systems and the airframe requires the readiness of every single developer to provide data to all colleagues even before completion of their task.

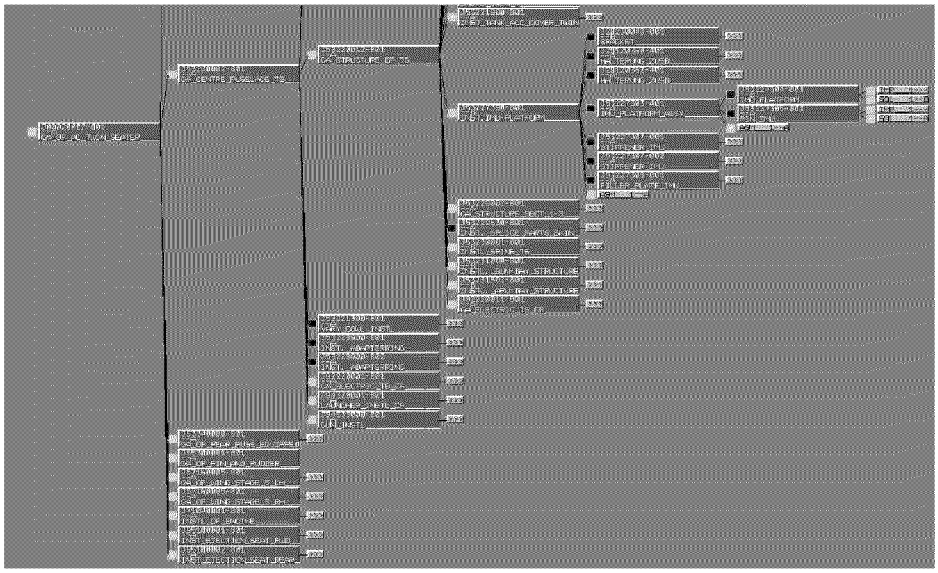

Fig. 3: Product structure in VPM

The DMU working process is implemented very early in the project phase, primarily creating a ‘rough product structure’. This is followed by defining the main components and relating them to each other (see fig.3). Step by step the first 3D-CAD models are attached to the product structure, resulting in the growth of the Digital Mock-up (see fig.4).

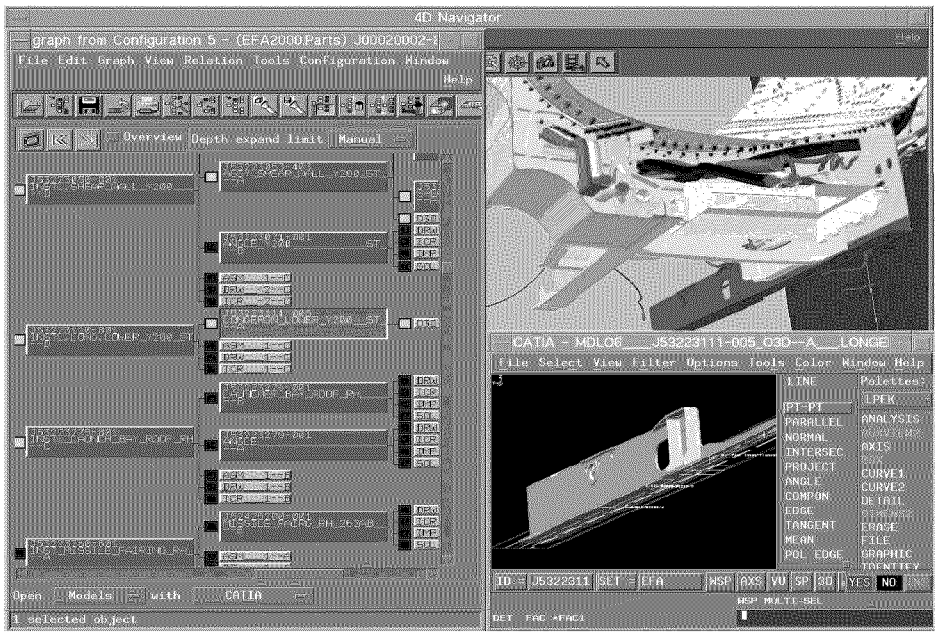

Fig. 4: Product structure linked with 3D–geometry , EnoviaVPM, 4D-Navigator, CATIA V4

The release status of parts and models must be clearly visible for all DMU users. This information is essential for all departments that work with the provided geometry to evaluate the possibility and probability of changes.

The management of aircraft variants and effectivities is also absolutely necessary (see fig.5). As every military aircraft is somehow unique a detailed view on every single aircraft must be possible. This can only be achieved with a sensible effectivity control module.
As modifications on in-service aircraft are carried out for single aircraft, national fleets or special serial numbers the designers must be able to filter the needed product structure for the selected configuration.

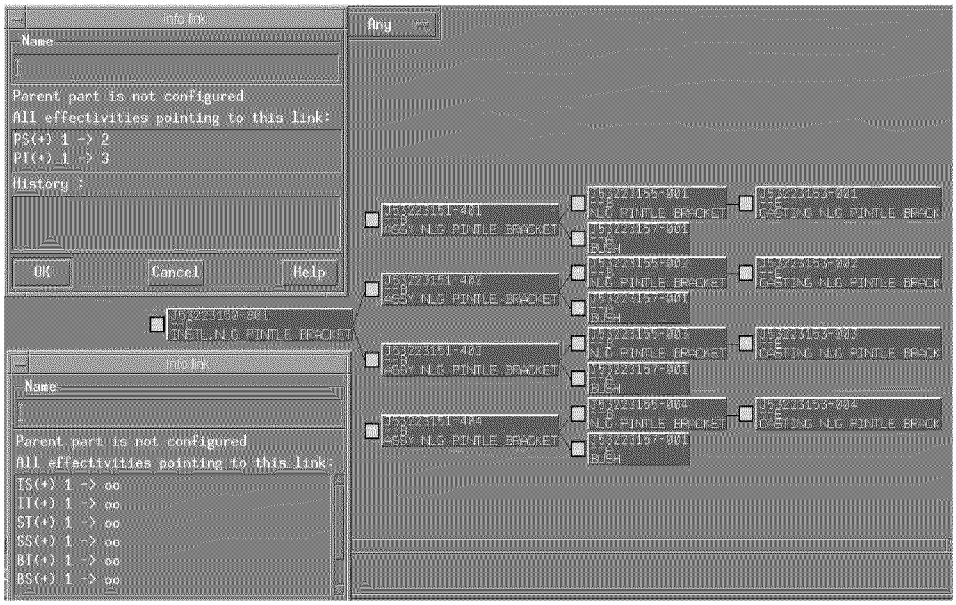

Fig. 5: Product structure links with effectivities only for selected aircraft

The daily work in a virtual environment now makes it possible to identify problem areas right from the beginning when modelling parts. Solutions can be found long before the first activities of manufacturing have begun:
Volume and neighbourhood queries enable design in context and parallel development. Time intensive manual searches for the design environment are therefore eliminated.
Let's take a designer of the hydraulic system for example. A frequent job is to create a hydraulic pipe from point A to point B. Therefore he needs to know all the surrounding geometry like fuel pipes, equipment, electrical cables, structure etc. As all those parts belong to different systems they are all shown in different branches of the product structure and on different installation drawings. Without the help of the data management system it is nearly impossible to find all the necessary geometry.

Therefore the system must enable queries that search for all parts in a selected aircraft zone and/or in the neighbourhood of a selected item.

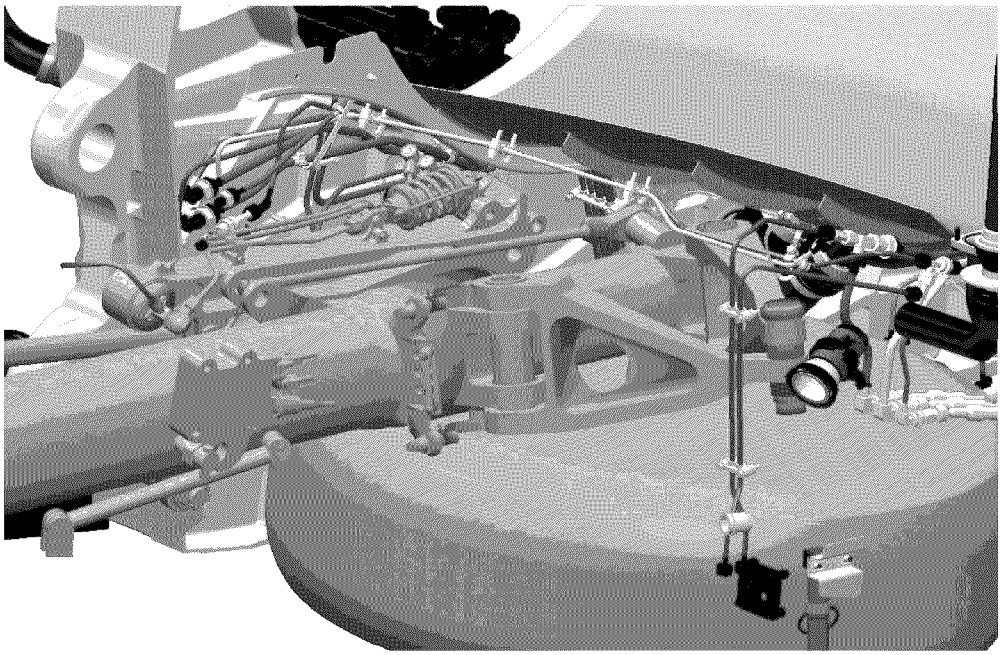

Fig. 6: Result of neighbourhood query (box defining a hydraulic pipe)

The result of this neighbourhood query can be loaded into a visualisation tool like 4D-Navigator (see fig. 6), the important parts can be selected, loaded into the 3D-CAD tool and used as passive models during design of the part “under construction”.

Again with the help of the visualisation tool, collision checks between one or several selected parts and all the surrounding items can be performed.
Therefore interdisciplinary collision analysis early on in the design phase will reduce the amount of occurring problems during manufacturing and assembly. (see fig. 7)

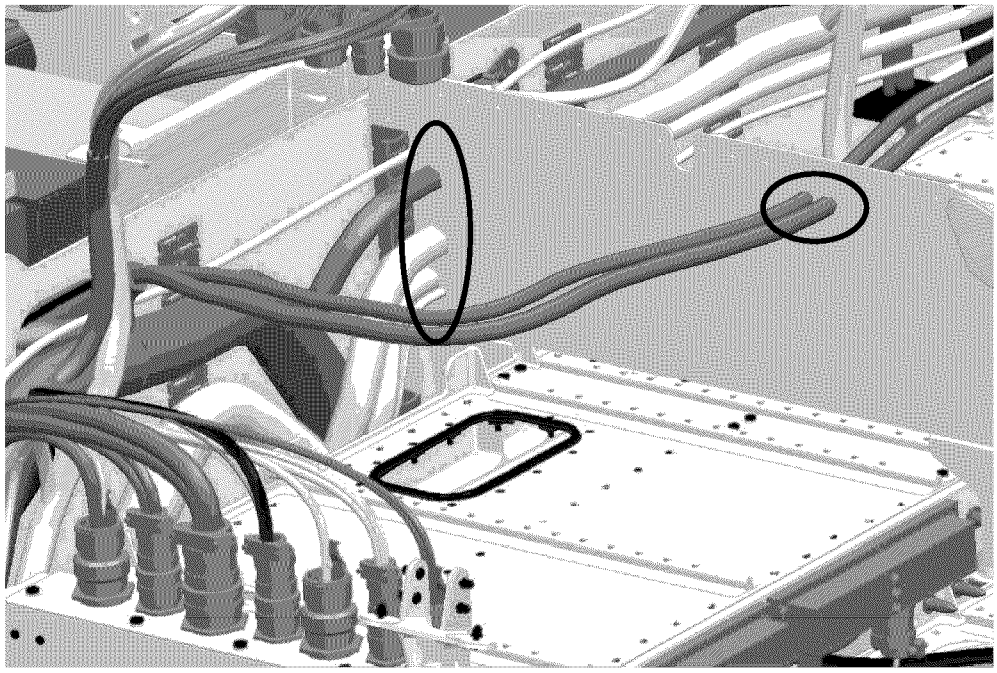

Fig. 7: Result of interdisciplinary collision analysis: Problems found in an early stage of the design phase enable a solution before the first part is manufactured

Possible installation and de-installation investigations are invaluable for future maintainability and reparability purposes.
Certainly, virtual installations are not so easy to perform as “real-life” installations on a hardware mock-up. But in the DMU environment these checks can be done on any configuration and with parts that do not yet exist as hardware. (see fig. 8)

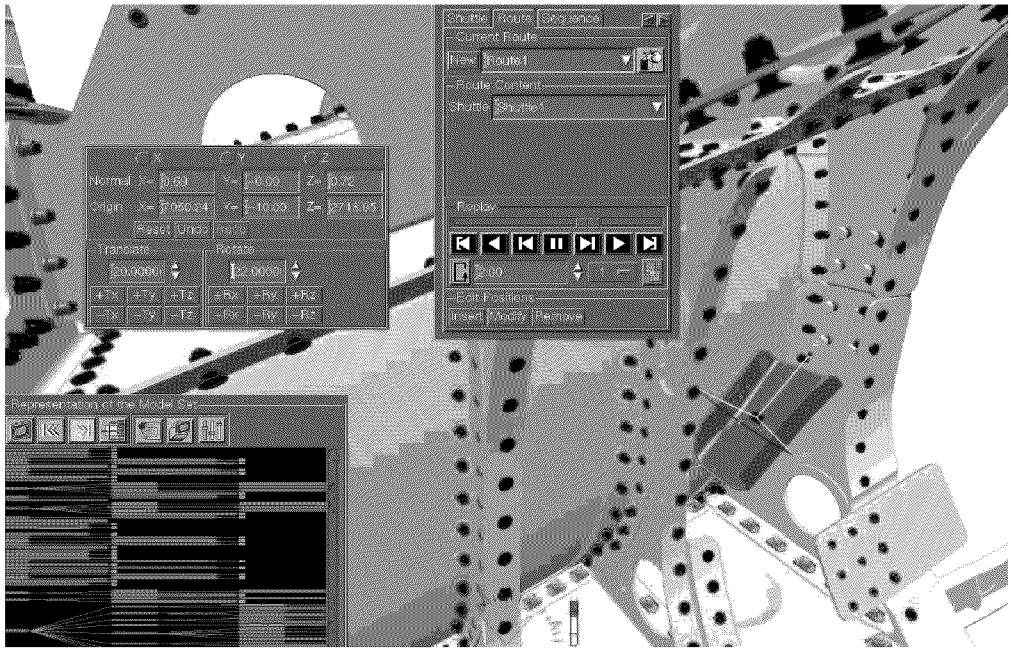

Fig. 8: Disassembly Analysis

Design conferences aided by the virtual environment enable quick solution of problems within the development team. It is no longer required to meet all the affected departments all the time for problem solving at the aircraft assembly line. This is very helpful especially when the design departments are located far away from manufacturing. (see fig. 9)

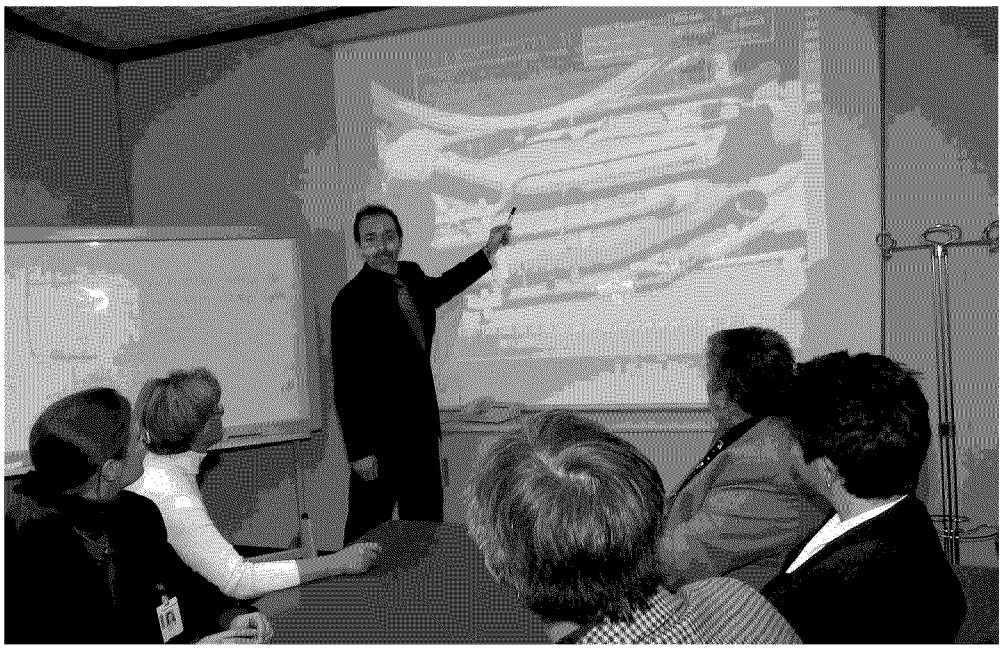

Fig. 9: Design conference supported by the virtual environment

4. Introduction of a DMU Process

Occurring Problems during introduction

The introduction of a new working methodology, coupled with the introduction of 'State of the Art' software, like any new technology comes with a lot of inherit problems initially, such as:

- Change over to a complete 3D design process initially causes additional work in the design office as much more data has to be fed into the system
- The implementation of a new system for an existing project causes problems during the transition period:
  - Because the quality of the old data is insufficient
  - Existing processes have to be changed without delaying the project
  - A tight timeframe for the current project leads to a minimum acceptance of failure on the side of the user
- Personnel will require extensive training in order to fully utilise the new system, some more than others!
- Insufficient software maturity and documentation make the required modifications in the new systems even more complicated
- There are only a few software specialists available on the market

The Implementation at EADS Military Aircraft

EADS Military Aircraft, faced with the problems described above, searched for the optimum solution. A direct result of this was the foundation of a small team to act as a service provider for the project as a whole, at the beginning. This team consisted of well accepted colleagues from various departments, who were responsible for introducing the new process in small steps. Lessons have been learned from the past that with a process covering multiple interfaces confusion is caused by its introduction in one step, therefore new functionalities were only invented after all existing features had been accepted by the users. Step by step the team was supported by "superusers" from all departments concerned.
The availability of continuous system support during the initial phase and the attempt to clarify the concepts with various demonstrations, ultimately led to a widespread overall acceptance of the new system and the new working processes by the users.

The Benefits

The benefits achieved by the introduction of a data management tool in context with a 3D-CAD system and a visualisation software can be realised in different areas of the process chain:

Reduction of iteration loops by a better first design
Increase of product quality, as the system promotes a 'Get it Right First Time' philosophy, thus avoiding unnecessary changes or repairs before delivery
Improvement of the product by greater consideration given to aspects of maintainability and reparability
Faster Design due to much more efficient search mechanisms
Avoidance of mechanical mock-ups
Omission of extensive support for departments outside the design office (e.g. product support, assembly).
Potential for distributed development in an international partnership

Open Problems

Unfortunately no available PDM system on the market is able to meet all the requirements of paragraph 2. Some tools have their strength in the management of different kinds of product structures, some in the handling of geometry, others in configuration control. Even with extensive customising it is not possible to satisfy all the company's needs with one software. This leads very often to a coexistence of several systems with the distinct disadvantage of data duplication.

Another topic under discussion is the exchange of data with partners or suppliers. Most PDM systems offer STEP interfaces that are theoretically able to transfer all the necessary information from one PDM system to another. Some attempts were already successful. But in general those STEP processors need a lot of customising. Especially in the data exchange between two big companies with a lot of different tools, data structures and data items it is hard to find a common basis. Other difficulties appear in the data exchange with suppliers that have no data management system at all. A preferable online data access seems also to be complicated as CAD data due to it's large size, needs a lot of time to be transferred. Also security problems delay the realisation of data sharing.

5. Summary

Summing up it can be said that in future the Digital Mock-up will be the backbone of all activities in the development process of all complex products.
However the purchase of new software on its own is not sufficient to change the working process. An over all cultural change throughout the organisation is needed to support the technology and new processes. This coupled with detailed know-how of all tools available (including existing processes) will assure the overall success of the implementation. Only with this background can a virtual working environment be created and the enormous possibilities that are on offer by the new tools be fully exploited.

Paper #2
Discussor's name Bochenek
Author Kaun

Q: You mentioned that one of the major issues preventing full use of digital design is the "security" need and requirements. How is EADS handling this?

A: Security is a big issue and currently not resolved
Looking at encryption devices and direct network connection with partners

Discussor's name F. Kafyeke
Author Kaun

Q: What is the CAD software you use for the digital mockup?

A: CATIA v4